



88136103


CHEMISTRY
HIGHER LEVEL
PAPER 3

Candidate session number

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Tuesday 19 November 2013 (morning)

Examination code

1 hour 15 minutes

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INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all of the questions from two of the Options.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **Chemistry Data Booklet** is required for this paper.
- The maximum mark for this examination paper is [50 marks].

Option	Questions
Option A — Modern analytical chemistry	1 – 5
Option B — Human biochemistry	6 – 9
Option C — Chemistry in industry and technology	10 – 13
Option D — Medicines and drugs	14 – 18
Option E — Environmental chemistry	19 – 22
Option F — Food chemistry	23 – 26
Option G — Further organic chemistry	27 – 30



52EP01

Option A — Modern analytical chemistry

1. Magnetic resonance imaging (MRI) is a diagnostic technique in which protons, in water and other molecules inside a patient, interact with a magnetic field.

(a) State the property of protons that allows them to be detected by MRI.

[1]

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(b) State **one** advantage, other than reducing health risks, of using MRI rather than X-ray radiography.

[1]

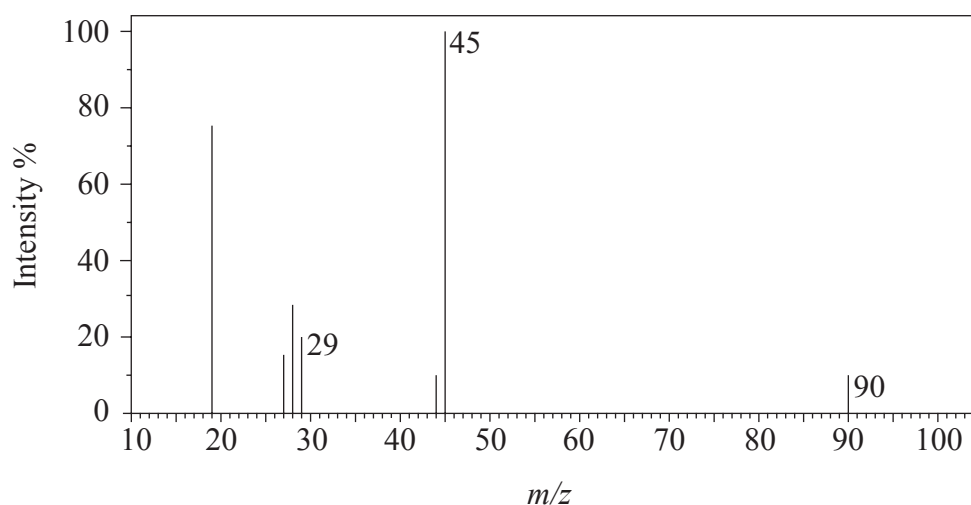
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(Option A continues on the following page)



(Option A continued)

2. (a) The mass spectrum of an unknown acidic compound, **X**, with empirical formula CH_2O , is shown below.



- (i) Determine the relative molecular mass, to the nearest integer, of the compound from the mass spectrum and deduce the formula of the molecular ion. [2]

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- (ii) Deduce the formula of the fragment responsible for the peak at 45. [1]

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- (iii) Deduce the formula of the fragment responsible for the peak at 29. [1]

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(Option A continues on the following page)

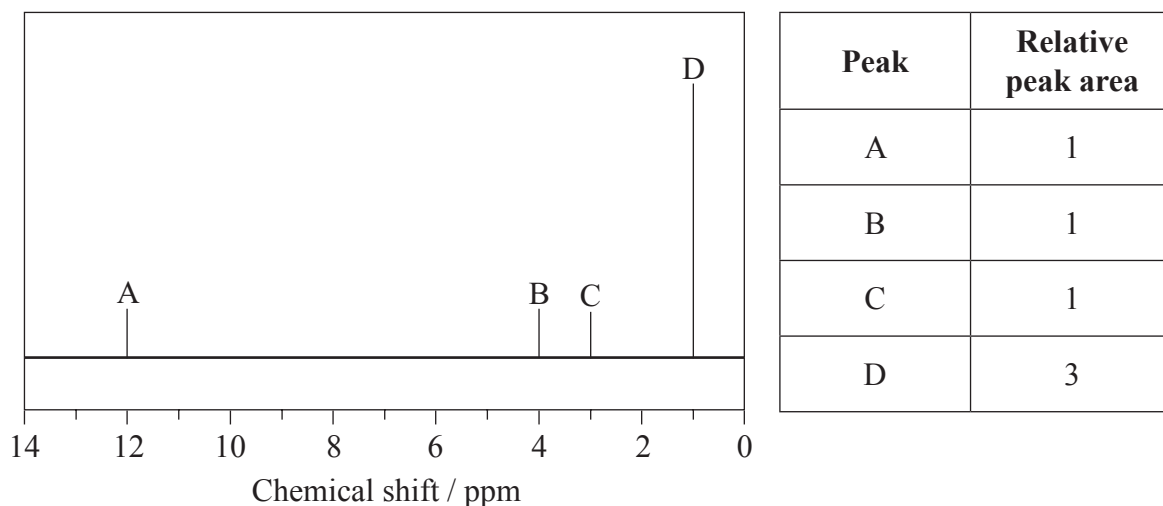


52EP03

Turn over

(Option A, question 2 continued)

- (b) The low-resolution ^1H NMR spectrum of **X** shows four peaks. A simplified representation is shown alongside a table with relative peak areas.



- (i) Identify the group responsible for the peak at **D**. [1]

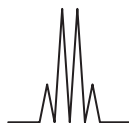
- (ii) Suggest a possible structure for **X**. [1]

(Option A continues on the following page)



(Option A, question 2 continued)

- (c) Peak **B** shows the following splitting pattern in the high-resolution spectrum.



Explain the splitting pattern, indicating the hydrogen responsible for peak **B**.

[3]

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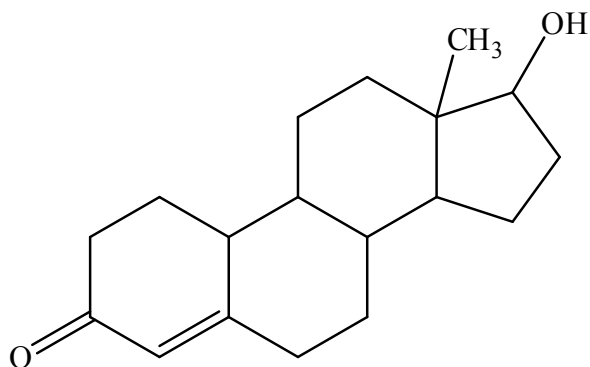
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(Option A continues on the following page)

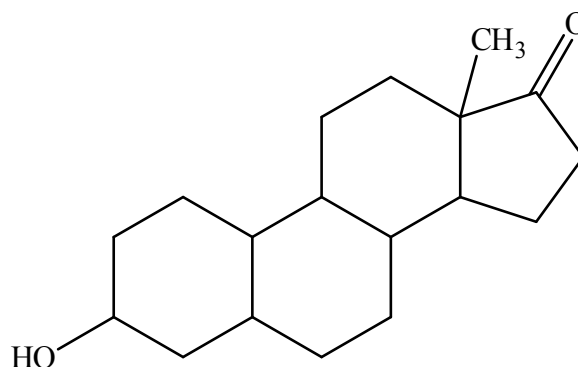


(Option A continued)

3. Some famous athletes have been banned from competing after failing tests for the drug nandrolone. The molecule changes in the body and is excreted as norandrosterone, which can be detected in urine samples.



Nandrolone



Norandrosterone

- (a) The characteristic ranges for infrared absorptions are shown in Table 17 of the Data Booklet. Identify **two** ranges in which the infrared spectra of nandrolone and norandrosterone would be similar and **one** range in which they would differ. [3]

Two similarities:

.....

One difference:

.....

(Option A continues on the following page)



(Option A, question 3 continued)

- (b) The International Olympic Committee has set a legal limit of $2.0 \times 10^{-9} \text{ g cm}^{-3}$ for norandrosterone in urine. Suggest why high-performance liquid chromatography (HPLC) is used to determine the norandrosterone concentration. [2]

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- (c) Nandrolone and norandrosterone can also be distinguished using ultraviolet spectroscopy. Identify the features that allow both molecules to absorb UV radiation. [1]

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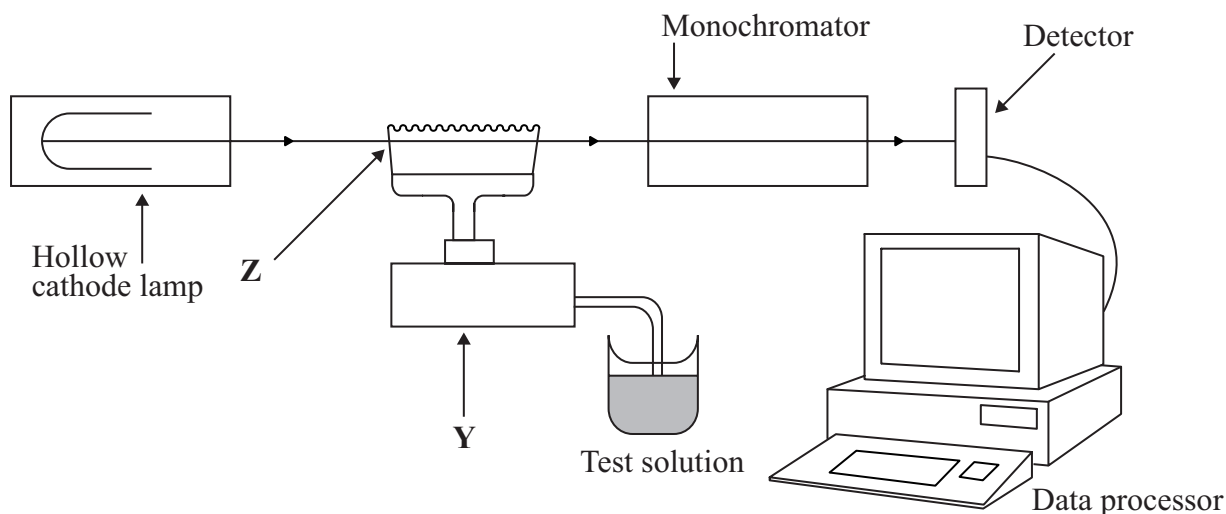
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(Option A continues on the following page)



(Option A continued)

4. Aluminium salts are widely used in water treatment, but levels need to be continually monitored because high exposure to Al^{3+} ions may increase the risk of Alzheimer's disease. A sample of drinking water was analysed using atomic absorption (AA) spectroscopy. A simplified diagram of the AA spectrometer is shown below.



- (a) Outline the essential characteristics of the hollow cathode lamp. [1]

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- (b) Describe the changes that the sample undergoes at Y and Z. [2]

Y:

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Z:

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(Option A continues on the following page)



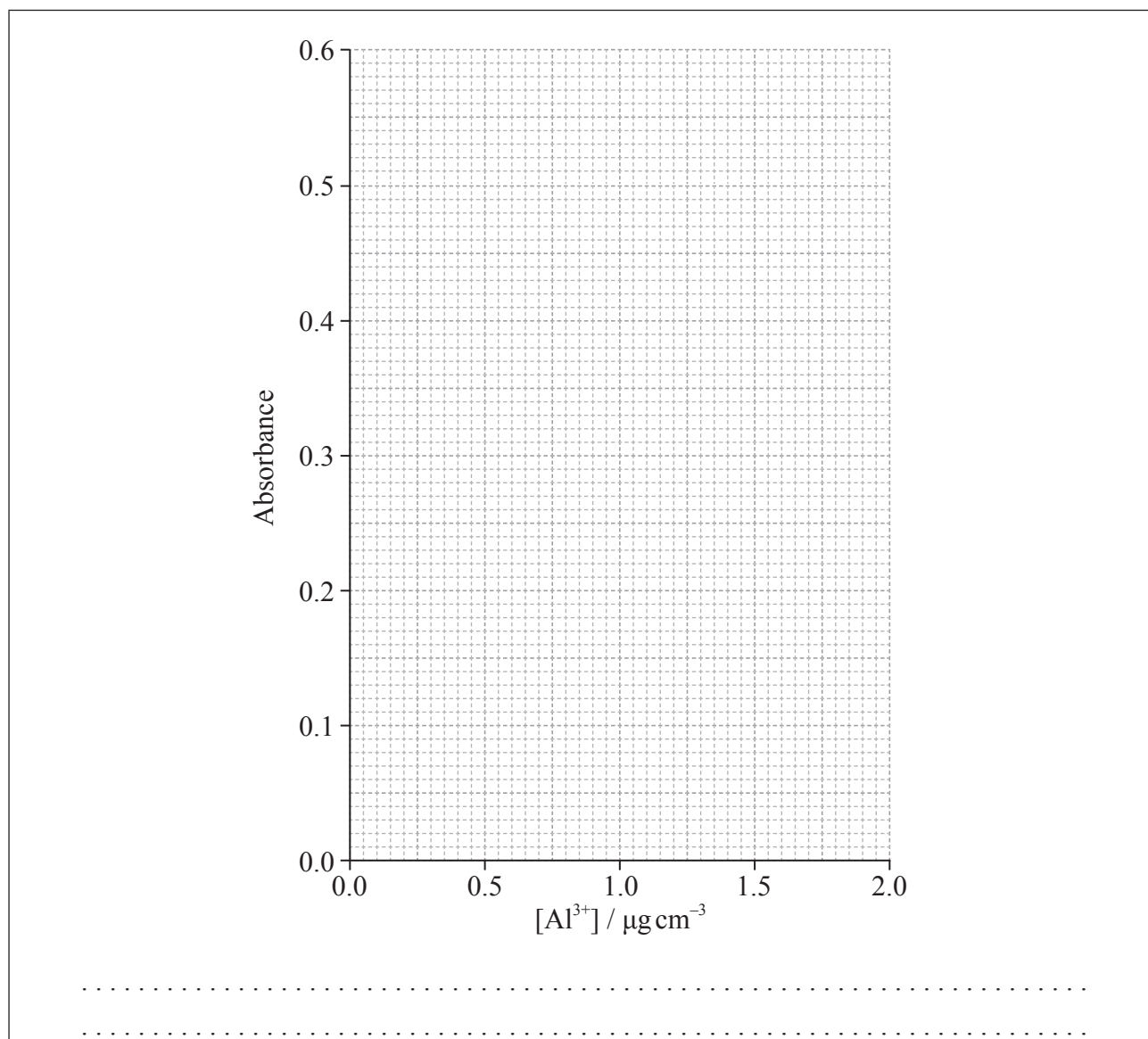
(Option A, question 4 continued)

- (c) The AA spectrometer was calibrated and the following results were obtained.

$[\text{Al}^{3+}] / \mu\text{g cm}^{-3}$	Absorbance ($\lambda_{\text{max}} = 535\text{ nm}$)
0.00	0.00
0.50	0.15
0.75	0.22
1.00	0.29
1.50	0.44
2.00	0.58
Unknown sample	0.49

Draw a calibration curve on the grid provided and determine the concentration, in $\mu\text{g cm}^{-3}$, of Al^{3+} ions in the unknown sample.

[2]



(Option A continues on the following page)

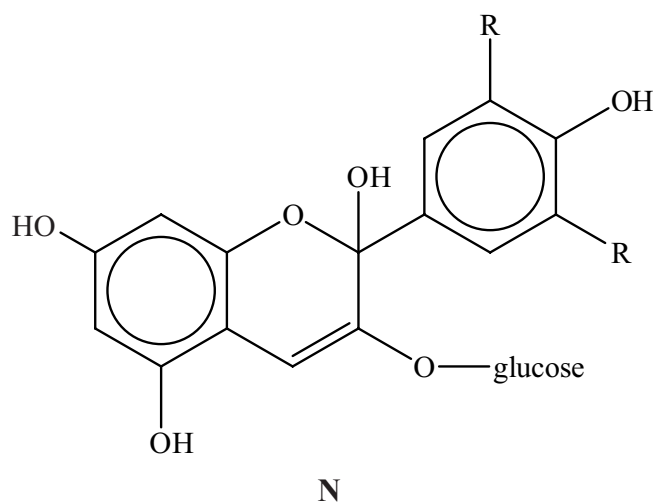
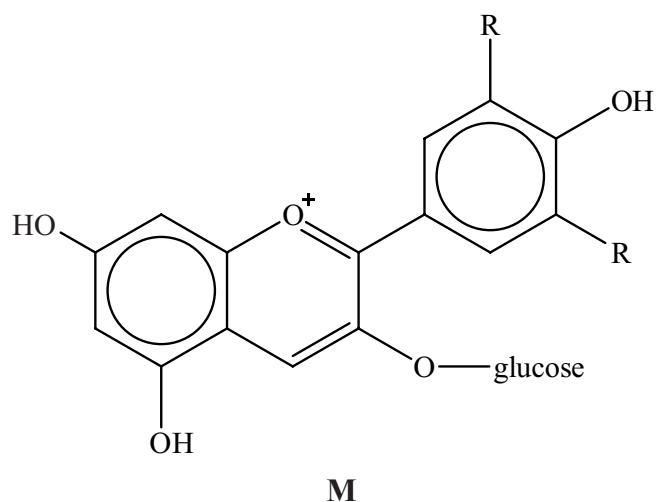


52EP09

Turn over

(Option A continued)

5. A natural pigment found in cranberries can exist in two forms.



Explain, with reference to hybridization, which form is more likely to be coloured.

[3]

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End of Option A



Option B — Human biochemistry

6. Vitamins are organic micronutrients essential for good health. The structures of vitamins A, C and D are given in Table 21 of the Data Booklet.

- (a) Identify by name **two** functional groups that are common to all three of these vitamins. [1]

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- (b) Only one of these three vitamins is soluble in water.

- (i) Identify this vitamin. [1]

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- (ii) Explain why this vitamin is soluble in water. [2]

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(Option B continues on the following page)



(Option B, question 6 continued)

- (c) Vitamin D is the only vitamin that can be synthesized in the body, by the action of sunlight on the skin.

- (i) State **one** effect of vitamin D deficiency.

[1]

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- (ii) Suggest why vitamin D deficiency diseases are becoming increasingly common in young people.

[1]

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7. Proteins are polymers of 2-amino acids. The structures of the common amino acids are given in Table 19 of the Data Booklet. This question refers to the two amino acids alanine and cysteine.

- (a) State the structural formula of cysteine as a zwitterion.

[1]

(Option B continues on the following page)



(Option B, question 7 continued)

- (b) With reference to the isoelectric points of alanine and cysteine, describe with a reason what pH value would be suitable to use in an electrophoresis experiment designed to separate these two amino acids in solution. [2]

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- (c) Cysteine is responsible for a specific type of intra-molecular bonding within a protein molecule. State the name of this type of interaction and outline how it is different from other interactions responsible for the tertiary structure. [2]

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(Option B continues on the following page)



(Option B continued)

8. The following products result from the hydrolysis of a triglyceride.



- (a) Draw a possible structure for the triglyceride.

[1]

- (b) State the other reactant and one essential condition that would favour this hydrolysis reaction in the body.

[1]

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- (c) Identify which product is polyunsaturated, and outline why foods containing this type of fatty acid are important for health.

[2]

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(Option B continues on the following page)



(Option B continued)

9. Enzymes are catalysts that increase the rate of all biochemical reactions, including those involved in respiration.

(a) Compare enzymes and inorganic catalysts with respect to their structure and mode of action. [4]

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(b) Cytochrome oxidase is a complex enzyme that catalyses the reduction of oxygen in the final stage of aerobic respiration. This enzyme is inhibited both by nitrogen(II) oxide, NO, and separately by cyanide ions, CN⁻. It has been suggested that NO acts competitively while CN⁻ acts non-competitively in inhibiting the enzyme. Experiments were carried out to test this hypothesis.

(i) State the metal ions present in cytochrome oxidase. [1]

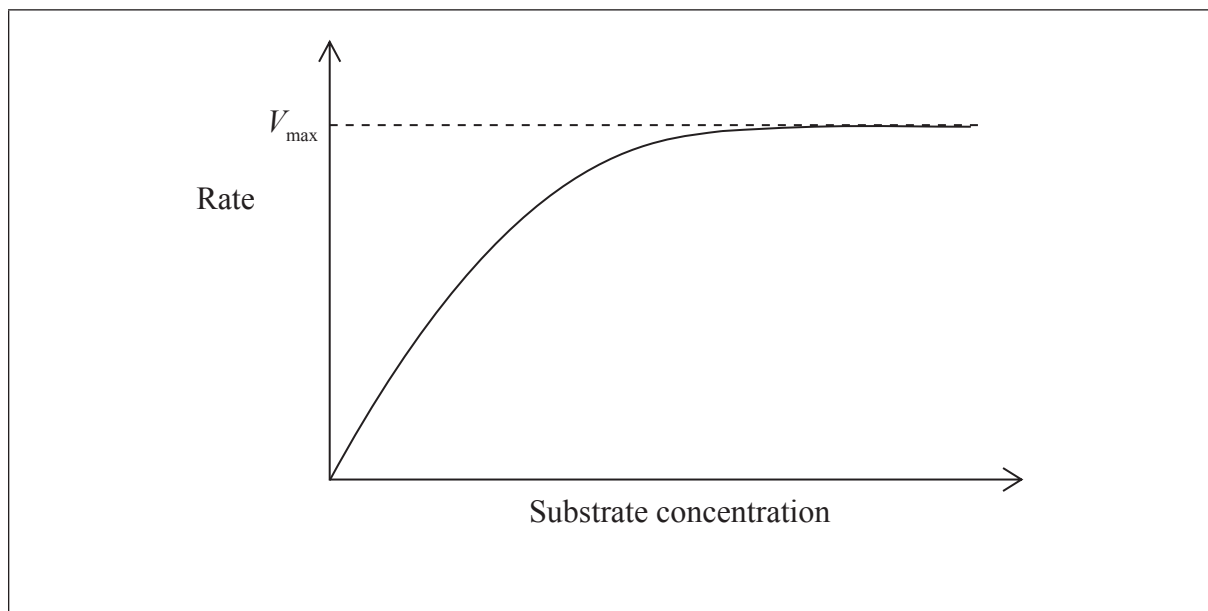
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(Option B continues on the following page)



(Option B, question 9 continued)

- (ii) The graph below shows the effect of substrate concentration on the rate of the reaction in the absence of an inhibitor. Draw and label the results of the **two** experiments showing how the rate of the reaction changes in the presence of NO and in the presence of CN^- , if the hypothesis is correct. [2]



- (iii) Suggest a reason why it is more likely that NO, rather than CN^- , acts competitively. [1]

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- (iv) The reducing agent in the cytochrome oxidase reaction is a species that can be denoted as XH_2 in the reduced form. Using this notation, deduce an equation for the reaction of XH_2 and O_2 , and outline, using oxidation numbers, why it is a redox reaction. [2]

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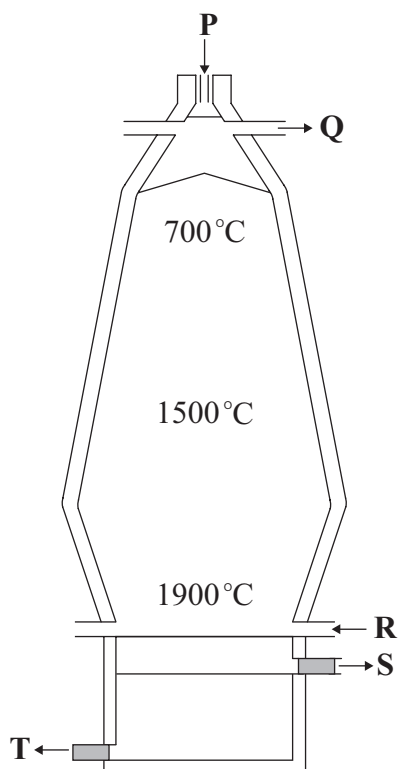
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End of Option B



Option C — Chemistry in industry and technology

- 10.** Iron ore can be reduced in a blast furnace.



- (a) State the name of an iron ore used and identify which letter, in the diagram above, shows where the iron ore is added. [1]

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(Option C continues on the following page)



(Option C, question 10 continued)

- (b) (i) State the name of substance **S**.

[1]

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- (ii) Deduce an equation for the formation of **S** from the raw materials.

[1]

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- (c) The properties of a metal can be altered by alloying or heat treatment. Explain why alloying can modify the structure and properties of a metal.

[2]

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(Option C continues on the following page)



(Option C continued)

11. Polyethene is the world's most widely used polymer. It can exist in two forms with distinctive physical properties.

The manufacture of low-density polyethene (LDPE) is initiated by the introduction into ethene of an organic peroxide, ROOR, which, at high temperature and pressure, forms free radicals.



- (a) State equations to show the mechanism by which the carbon chain increases in length during the polymerization process. [2]

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- (b) LDPE has a low density because the polymer chains have a branched structure. Outline the mechanism that can lead to the formation of branched chain structures. [1]

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- (c) High-density polyethene (HDPE) is formed under different experimental conditions from LDPE. State the type of catalyst used in the formation of HDPE. [1]

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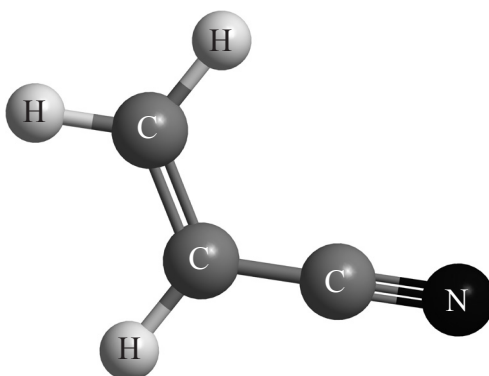
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(Option C continues on the following page)



(Option C, question 11 continued)

- (d) Polyacrylonitrile is an important polymer used in the manufacture of carbon fibres. The monomer has the structure below.



Polyacrylonitrile is similar to polypropene and can exist in two forms.

- (i) Draw the structure of the isotactic form of polyacrylonitrile showing **three** repeating units. [2]

- (ii) Explain why the isotactic form is more suitable for the manufacture of strong fibres. [2]

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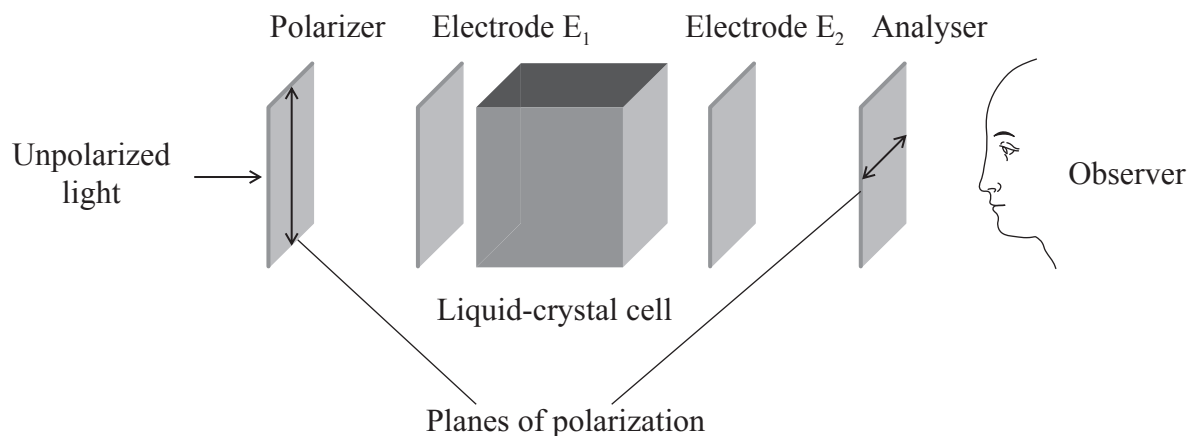
(Option C continues on the following page)



(Option C continued)

12. Chemistry has made a significant contribution to the development of liquid-crystal displays (LCDs).

The diagram below is a representation of an LCD. The planes of polarization of the analyser and the polarizer are at right angles to each other.



- (a) State what the observer would see if the liquid crystal was not present and there was no voltage between the electrodes E_1 and E_2 . [1]

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- (b) (i) Explain how the addition of a liquid crystal to the cell changes what the observer sees. [2]

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(Option C continues on the following page)



(Option C, question 12 continued)

- (ii) Explain how the application of an electric field between the electrodes, E_1 and E_2 , changes what the observer sees in b (i). [2]

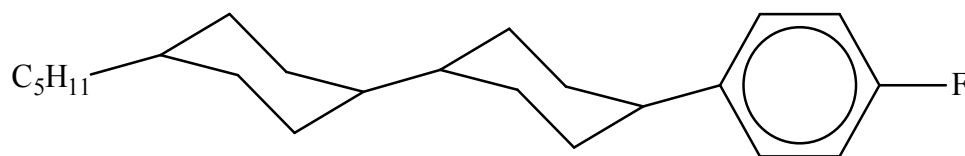
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- (c) The molecule below has liquid-crystal display properties.



Suggest **two** reasons why the molecule is suitable for use in liquid-crystal display devices. [2]

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(Option C continues on the following page)



(Option C continued)

13. Nickel-cadmium cells are used to power portable machinery or large tools.

- (a) State the equation, including state symbols, for the reaction that takes place when the cell is discharging. [2]

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- (b) State the physical property of the products that allows this process to be reversed and the cell recharged. [1]

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- (c) Pure silicon is a semiconductor but its conductivity can be increased when it is doped with small amounts of another element. Describe how the addition of small amounts of arsenic increases the conductivity of silicon. [2]

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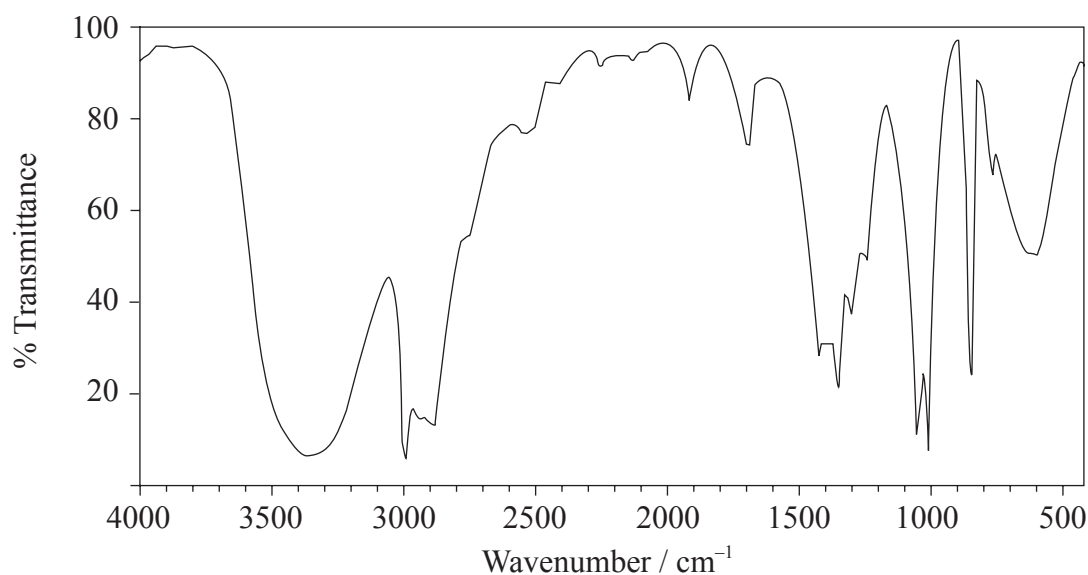
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End of Option C



Option D — Medicines and drugs

14. A modern method for accurately determining ethanol concentrations in the breath is based on the infrared (IR) spectrum of the molecule.



- (a) (i) Use Table 17 of the Data Booklet to identify the wavenumber range used in the determination. [1]

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- (ii) State why the absorption in the range 3200 to 3600 cm^{-1} is not used. [1]

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- (b) The concentration of ethanol is determined by passing IR radiation through a breath sample. Outline how the transmittance of IR radiation changes when increased levels of ethanol are present. [1]

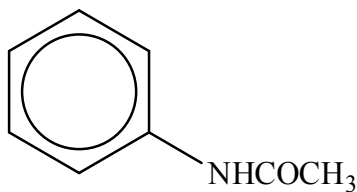
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(Option D continues on the following page)



(Option D continued)

15. The drug Antifebrin was first used as a medicine in 1886.



Antifebrin

(a) The structures of some medicines and drugs are given in Table 20 of the Data Booklet.

(i) Identify the molecule which is most similar to Antifebrin in terms of size and structure. [1]

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(ii) State the names of the **two** functional groups that both molecules have in common. [1]

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(b) The action of a drug can depend on its polarity and shape, so similar molecules can have similar effects on the body. Suggest **one** physiological effect of taking Antifebrin. [1]

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(Option D continues on the following page)



(Option D, question 15 continued)

- (c) Outline why some drugs can be less effective when taken orally rather than through other methods of administration. [1]

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- (d) The idea of combinatorial chemistry stems from the work of the US chemist Robert Merrifield. He developed semi-automatic methods for making peptides from amino acids and was awarded the Nobel Prize for this work in 1984.

Explain the “mix and split” (synthesis of mixtures) approach to combinatorial chemistry. [3]

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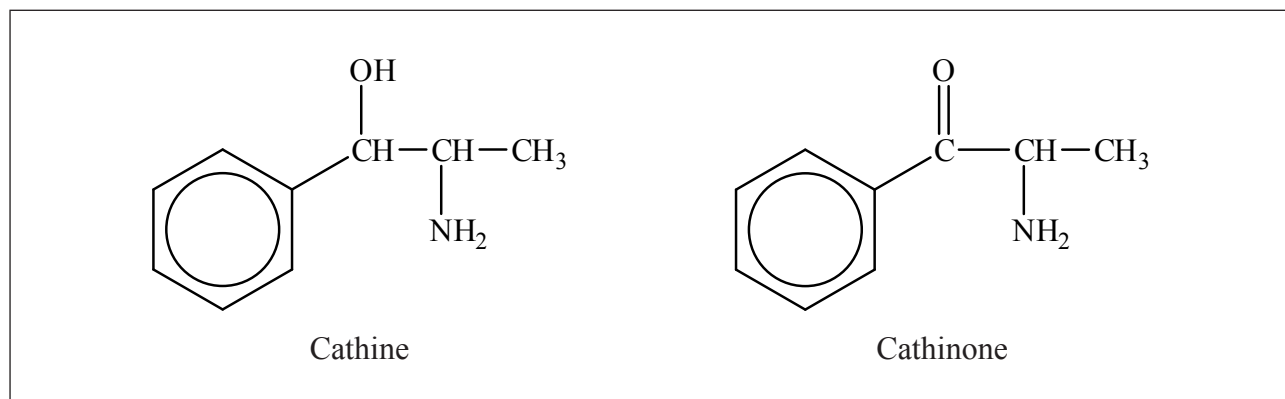
(Option D continues on the following page)



(Option D continued)

16. There is some concern that increased use of the recreational drug khat is causing social problems.

The structures of two substances found in khat are shown below.



Cathine and cathinone are both classed as sympathomimetic drugs.

- (a) Identify the structural features these two substances have in common with other sympathomimetic drugs shown in Table 20 of the Data Booklet. [1]

- (b) Both cathine and cathinone are optically active. Using an asterisk, *, label the chiral carbon atoms on the diagrams above. [1]

(Option D continues on the following page)



(Option D, question 16 continued)

(c) Phenylpropanolamine (PPA) is an optical isomer of cathine used in cough medicines.

- (i) Outline how PPA and not cathine could be synthesized from the same non-chiral starting materials. Details of reagents and conditions are not required. [3]

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- (ii) Explain why this is the generally preferred method for the synthesis of optically active drugs. [2]

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- (iii) Suggest how the aqueous solubility of cathine or PPA could be increased to facilitate its distribution around the body. [1]

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(Option D continues on the following page)



(Option D, question 16 continued)

- (d) Cannabis is one of the most commonly used recreational drugs and there is much debate about the legality of its use. Discuss **one** argument for and **one** argument against the legalization of cannabis.

[2]

For:

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Against:

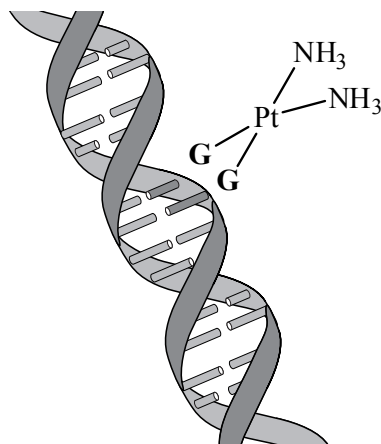
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(Option D continues on the following page)



(Option D continued)

17. The structure of the anti-cancer drug cisplatin is given in Table 20 of the Data Booklet. It prevents the replication of DNA by binding to adjacent guanine groups (G), which act as ligands as shown below.



Segment of DNA

- (a) Describe the bonding changes that occur when cisplatin attaches to the DNA chain. [1]

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- (b) Outline why the *trans* isomer is ineffective in the treatment of cancer. [1]

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(Option D continues on the following page)



(Option D continued)

- 18.** Acquired immune deficiency syndrome (AIDS), a disease caused by the HIV virus, has resulted in millions of deaths worldwide since it was first identified in 1981.

Explain why viral infections, such as AIDS, are generally more difficult to treat than bacterial infections.

[3]

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End of Option D



52EP31

Turn over

Option E — Environmental chemistry

19. (a) Outline the meaning of the term *biochemical oxygen demand* (BOD). [2]

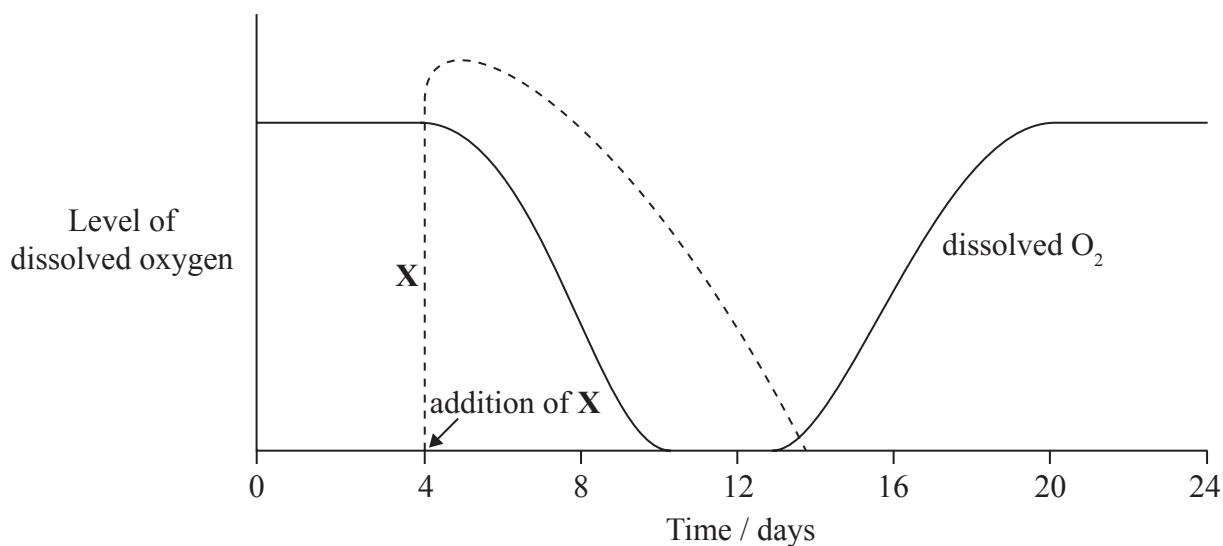
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- (b) The graph below shows the level of dissolved oxygen measured in the same location in a stream over a period of 24 days. The dashed line represents the concentration of substance **X** in the stream, which was introduced after 4 days.



(Option E continues on the following page)



(Option E, question 19 continued)

- (i) Outline why the concentration of dissolved oxygen falls between days 4 and 9. [1]

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- (ii) Describe why the concentration of dissolved oxygen changes between days 12 and 18. [2]

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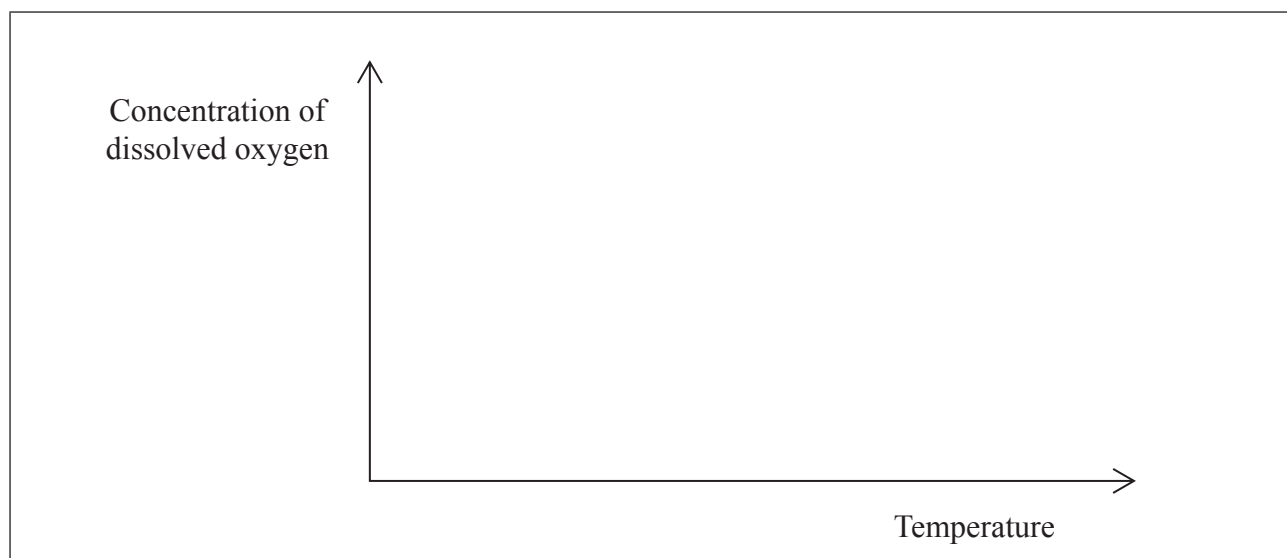
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- (iii) Identify the days during which the population of anaerobic bacteria will be highest. [1]

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- (c) A student did an experiment using digital probes to measure the effect of temperature on the concentration of dissolved oxygen in the stream. Sketch a graph of her expected results using the axes below. [1]



(Option E continues on the following page)



(Option E continued)

20. Soil degradation is a global problem that can lead to a reduction in food production.

- (a) The extent of soil degradation can be reduced by increasing the soil organic matter (SOM). Describe how the physical and biological functions of SOM improve the quality of the soil.

[2]

Physical:

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Biological:

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- (b) Aluminium and magnesium ions are commonly found in different forms in soil. Magnesium ions are important for plant growth, but aluminium ions may be toxic if absorbed by plants. Both these ions can be precipitated in the soil by the formation of their hydroxides. The K_{sp} values for magnesium hydroxide and aluminium hydroxide at 298 K are 1.80×10^{-11} and 3.00×10^{-34} , respectively.

- (i) Determine the concentration of the magnesium and hydroxide ions in a saturated solution of magnesium hydroxide at 298 K, and calculate its pH. Assume there are no other ions present.

[4]

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(Option E continues on the following page)



(Option E, question 20 continued)

- (ii) Deduce, with a reason, whether the pH of a saturated solution of aluminium hydroxide, at the same temperature, would be greater or less than your answer to (i). [1]

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- (iii) The toxicity of soil due to aluminium can be reduced by increasing the pH. Comment on this observation. [2]

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(Option E continues on the following page)



(Option E continued)

21. (a) The layer of ozone in the stratosphere, which plays an important role in helping to protect the Earth's surface from harmful radiation, is both formed and depleted by natural processes. State chemical equations that show the natural depletion of ozone, including the condition. [2]

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- (b) The ozone layer has also been depleted by certain pollutants that have been released into the atmosphere. State examples of **two** such ozone-depleting substances. [1]

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- (c) At ground level, ozone is a secondary pollutant present in photochemical smog.

- (i) Using equations, outline the formation of ozone in smog starting from nitrogen(II) oxide. [3]

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- (ii) Describe any **two** geographical features or meteorological conditions that cause ozone levels to rise. [1]

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(Option E continues on the following page)



(Option E continued)

22. Many countries obtain at least some of their power from nuclear energy. This process results in the production of waste, which can be classified as low-level or high-level radioactive waste. State **one** source of low-level radioactive waste, and a suitable method for its storage and/or disposal. [2]

Source:

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Storage/disposal method:

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End of Option E



Option F — Food chemistry

23. (a) The structures of three synthetic antioxidants, 2-BHA, 3-BHA and BHT, are given in Table 22 of the Data Booklet.

- (i) Identify by name **two** functional groups common to all **three** molecules. [1]

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- (ii) Suggest why all three molecules contain *tert*- in the prefix of their name. [1]

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- (iii) Deduce the molecular formula of BHT. [1]

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(Option F continues on the following page)



(Option F, question 23 continued)

- (b) Antioxidants delay the auto-oxidation process of fats and oils, which results in their rancidity. Some natural antioxidants, such as carotenoids, are thought to act differently from some synthetic antioxidants such as BHA and BHT. Explain how each type of antioxidant acts chemically in the process of auto-oxidation. [4]

Natural antioxidants:

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Synthetic antioxidants:

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- (c) The compound SO_2 can also act as an antioxidant. Suggest, with a reason, whether you think its mode of action is more likely to resemble that of the carotenoids or BHA and BHT. [1]

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(Option F continues on the following page)



(Option F, question 23 continued)

- (d) (i) State **two** examples of foods which contain large amounts of β -carotene. [1]

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- (ii) State the names of **two** other natural antioxidants, not including α -carotene. [1]

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(Option F continues on the following page)



(Option F continued)

24. Stearic acid, oleic acid and linolenic acid are all fatty acids that contain 18 carbon atoms. Their structures are given in Table 22 of the Data Booklet.

- (a) Explain which acid has the highest melting point. [3]

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- (b) State the equation for the complete hydrogenation of linolenic acid. Describe the conditions used for this reaction. [2]

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- (c) Partial hydrogenation of linolenic acid may lead to a product known as a *trans* fatty acid.

- (i) Explain the meaning of the term *trans*. [1]

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- (ii) Draw the structure of a possible *trans* fatty acid product. [1]

(Option F continues on the following page)



(Option F continued)

25. Many food substances involve different types of dispersed systems.

(a) State the meaning of a *dispersed system*.

[1]

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(b) Identify **one** emulsion and **one** foam from the following list of foods:

BEER	CREAM (UNWHIPPED)	UNCOOKED RICE
BUTTER	JAM	WHIPPED CREAM

[1]

Emulsion:

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Foam:

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(c) The preparation of some food substances involves the addition of chemicals to modify the texture of the food. Outline the structural features you would expect an emulsifier to possess.

[1]

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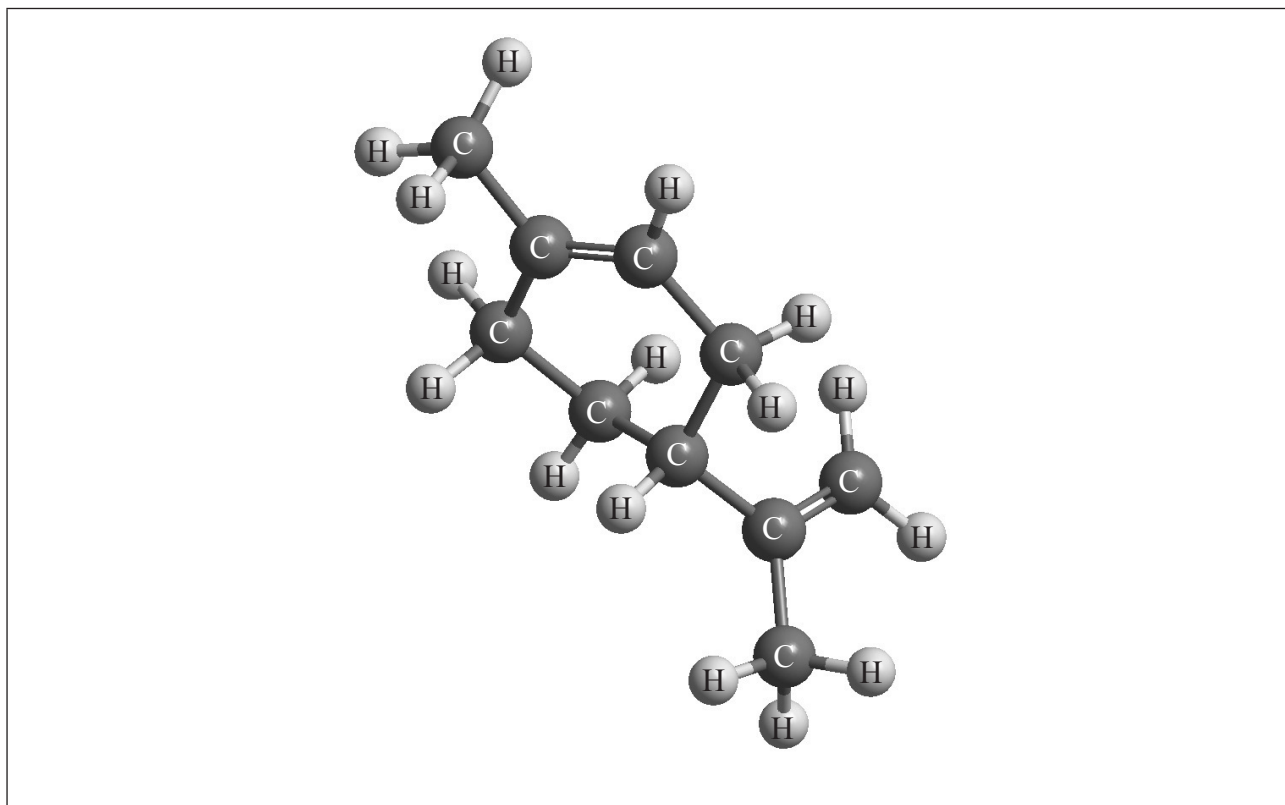
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(Option F continues on the following page)



(Option F continued)

26. Limonene is a chiral molecule. The enantiomer found in oranges is shown below.



- (a) Identify the chiral carbon atom in the structure above with an asterisk, *. [1]
- (b) The other enantiomer also occurs in foods. State **two** different ways in which these enantiomers might affect the properties of foods. [1]

.....

.....

(Option F continues on the following page)



(Option F, question 26 continued)

- (c) Limonene can be converted into a related molecule, carvone, by oxidation. The reaction does not affect the groups at the chiral carbon atom. Experiment A synthesized carvone using limonene obtained from a natural source. Experiment B synthesized carvone using limonene obtained from chemical synthesis. For each experiment, describe whether the carvone would be optically active.

[3]

Experiment A:

.....

Experiment B:

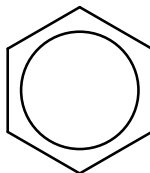
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End of Option F



Option G — Further organic chemistry

27. The bonding in benzene is one of the most challenging problems for chemists interested in explaining the bonding and structure of covalent molecules.



- (a) (i) Outline what the circle represents in the diagram above. [1]

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- (ii) Describe how the structure accounts for the C–C bond length in Table 9 of the Data Booklet. [1]

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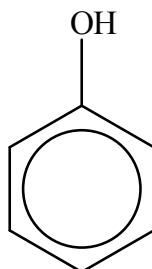
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(Option G continues on the following page)



(Option G, question 27 continued)

- (b) Phenol, which is also known as carbolic acid, was one of the first antiseptics used in medical surgery.



- (i) Explain why phenol is a stronger acid than ethanol. [2]

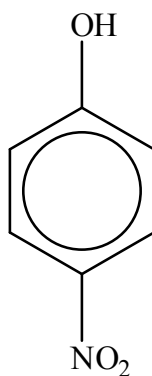
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- (ii) Explain how the presence of a nitro, NO_2 , group on the benzene ring increases the acidity of the OH group in the molecule below.



[2]

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(Option G continues on the following page)

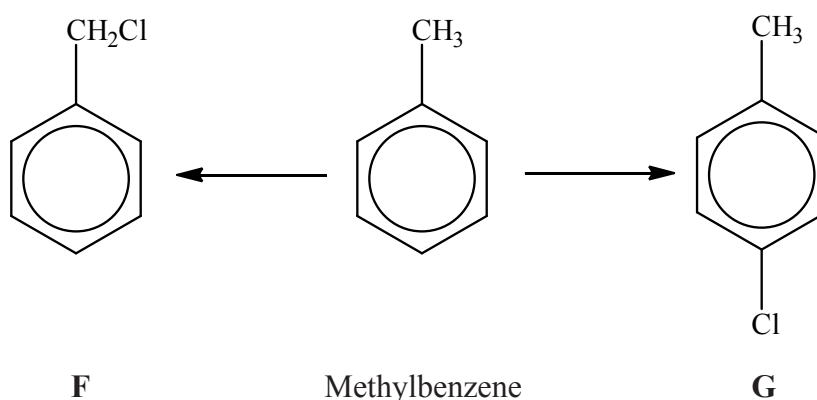


(Option G, question 27 continued)

- (iii) The NO_2 group can be introduced into the benzene ring using a mixture of concentrated nitric and concentrated sulfuric acids. Identify the species that attacks the benzene ring. [1]

.....

- (c) Methylbenzene can react with chlorine under different conditions to give the compounds **F** and **G**.



Describe the reagents and conditions required to produce each compound. [2]

Compound **F**:

.....

Compound **G**:

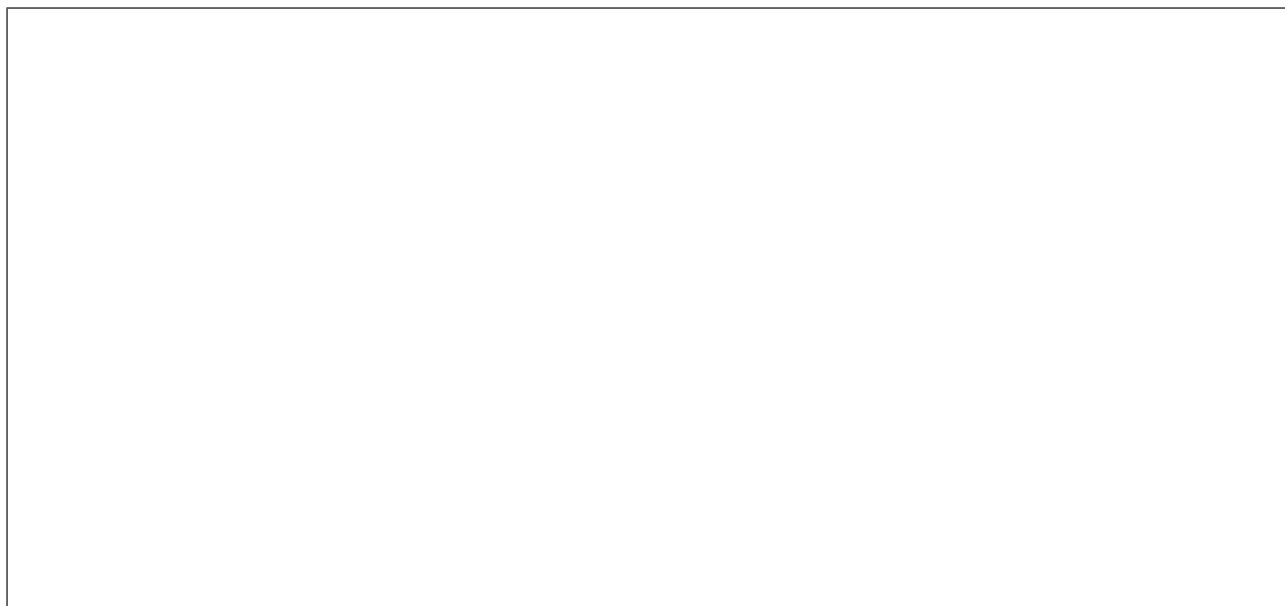
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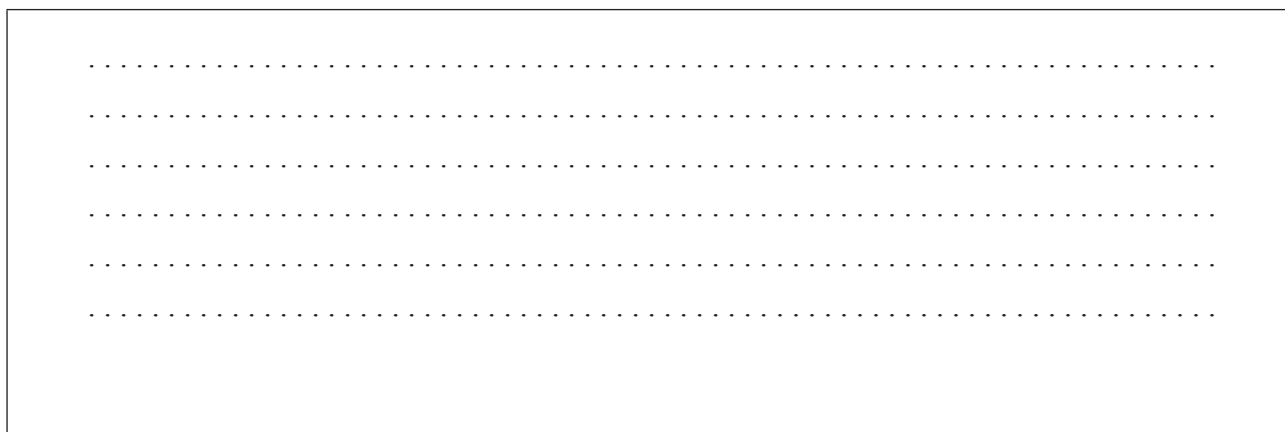


(Option G, question 27 continued)

- (d) Compound **H** is an isomer of **G** and is another major product formed from methylbenzene in the same reaction. Draw the structure of **H**. [1]



- (e) Outline why the isomers **G** and **H** are formed in preference to the other possible ring isomer of **G**. [2]



(Option G continues on the following page)



(Option G continued)

28. 2-chloropropane is the major product of the reaction between propene and hydrogen chloride.

- (a) Explain the mechanism of the reaction using curly arrows to represent the movement of electron pairs. [4]

- (b) Ethanal reacts with hydrogen cyanide.

- (i) State the equation for this reaction. [1]

.....

.....

- (ii) State the name of the mechanism of this reaction. [1]

.....

(Option G continues on the following page)



(Option G continued)

29. Victor Grignard was awarded the Nobel Prize in 1912 for the use of organomagnesium compounds in preparative organic chemistry.

- (a) State the structural formula of the Grignard reagent formed when bromoethane and magnesium react together in a non-polar solvent. [1]

.....

.....

- (b) Deduce the reagents required to convert the Grignard reagent in (a) into:

- (i) $\text{CH}_3\text{CH}_2\text{COOH}$

[1]

.....

.....

- (ii) $\text{CH}_3\text{CH}_2\text{C}(\text{CH}_3)_2\text{OH}$

[1]

.....

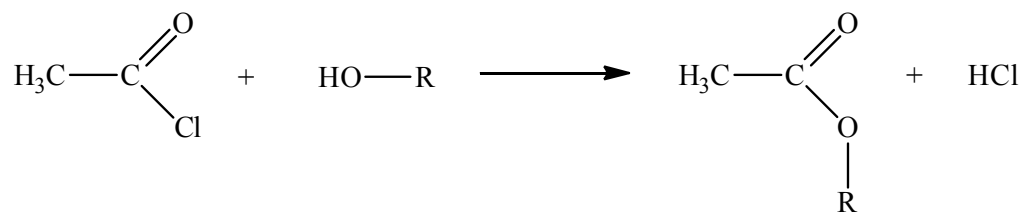
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(Option G continues on the following page)



(Option G continued)

30. Aspirin can be made by reacting 2-hydroxybenzoic acid with ethanoyl chloride. In the following equation, HO–R represents 2-hydroxybenzoic acid.



Explain the mechanism of this reaction using curly arrows to represent the movement of electron pairs.

[4]

End of Option G



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Answers written on this page
will not be marked.



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